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N94- 27900

AN EXPERIMENTAL INVESTIGATION OF FATIGUE DAMAGE IN ALUMINUM 2024-T3 ALLOYS

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Aluminum alloys are finding increasing use in the aerospace and automobile industries due to their attractive low density-high modulus and low density-high strength characteristics. Unfortunately, cyclic stress-strain deformation alters the microstructure of the material. These structural changes can lead to fatigue damage and ultimately service failure. Therefore, in order to assess the integrity of the alloy, a correlation between fatigue damage and a measurable microstructural property is needed.

Aluminum 2024-T3, a commonly used commercial alloy, contains many grains (individual crystals) of various orientations. The sizes and orientations of these grains are known to affect the strength, hardness, and magnetic permeability of polycrystalline alloys and metals (ref. 1); therefore, perhaps a relationship between a grain property and the fatigue state can be established. Tension-compression cycling in aluminum alloys can also induce changes in their dislocation densities. These changes can be studied from measurements of the the electrical resistivities of the materials. Consequently, the goals of this investigation were:

1. To study the grain orientation of aluminum 2024-T3 and to seek a correlation between the grain orientation and the fatigue state of the material.

2. To measure the electrical resistivities of fatigued samples of aluminum 2024-T3 and to interpret the findings.

X-ray diffraction analysis is an indicator of structural changes in materials due to deformations (ref. 2). However, in the present investigation, normal x-ray scans of aluminum 2024-T3 samples fatigued from 1,000 cycles to 300,000 cycles remained virtually unchanged. An especially sensitive technique for crystal structure analysis, the x -ray rocking curve (XRC), was then used to characterize the samples. The XRC is initiated by scanning the sample to find the Bragg angles. Subsequently, the sample is mounted on a goniometer at a particular Bragg angle and irradiated by a highly monochromatic x-ray beam while being rotated ("rocked") step by step about this angle. A plot of the reflecting power as a function of the angle between the sample surface and the incident x-ray is the rocking curve. The width of the rocking curve is a direct measure of the range of orientation of the grains present in the irradiated area of the sample. An increase in the width can also be correlated to an increase in the excess dislocation density of the material.

The electrical resistivity measurements were made using a "linear four-point probe". A direct current passed between two of the probes causes a potential difference between the other two probes. The resistivity is proportional to the ratio of the potential difference to the current, the proportional factor being dependent on the geometry of the probe array and the sample (ref. 3).

Fatiguing is believed to increase the excess dislocation density in the sample, thereby, causing the width of the rocking curve to increase with an increase in the number of fatigue cycles. Unexpectedly, the width of the XRC decreased. One explanation is that the samples annealed themselves after the fatiguing process, causing a reordering of the atoms into less distorted grains. The electrical resistivity measurements supported this explanation by decreasing as the fatigue state increased. Work is in progress to evaluate the effects of lapping on the width of the rocking curves and the resistivities of the samples.

References

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